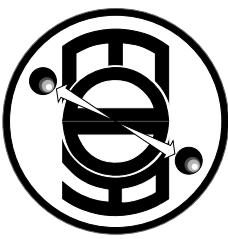


Results from the EDDA experiment at COSY: Spin observables in pp elastic scattering

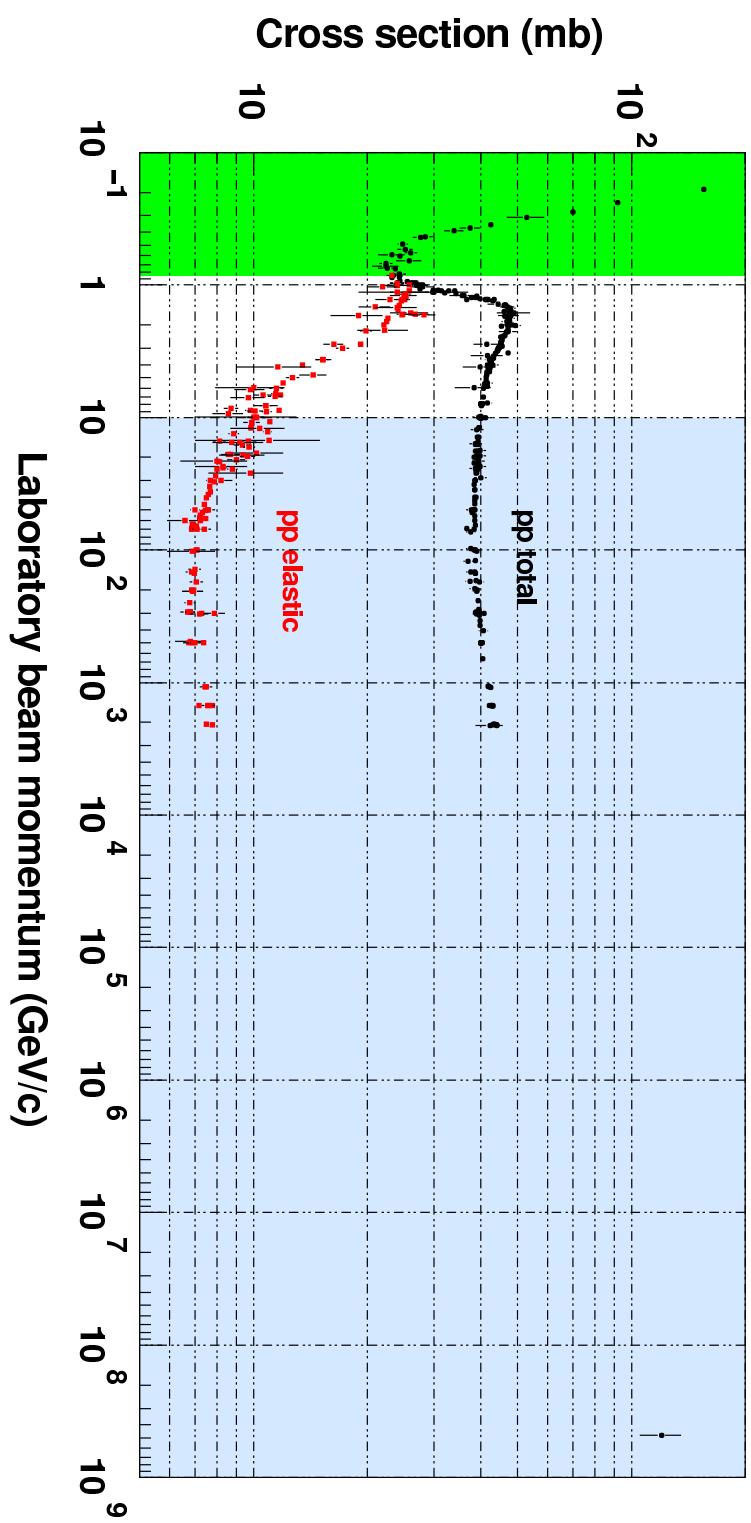


- Motivation
- The EDDA Experiment
- Experimental Results
 - Unpol. Diff. Cross Section
 - Analyzing Power
 - Spin Correlation Coefficients
- Influence of the EDDA Data
- Summary and Outlook

September 24th, 2002

Frank Bauer

Motivation



Low Energies $T_p \leq 350$ MeV

Phenom. Models / Meson Exchange
Nucleons and Mesons

High Energies $T_p > 10$ GeV

Quantumchromodynamics
Quarks and Gluons

No Theory at Intermediate Energies

Phase Shift Analyses



Nucleon-Nucleon Scattering:

- Described by scattering matrix M : $|\chi_f\rangle = M |\chi_i\rangle$
- M can be parameterized; 5 complex amplitudes are necessary.

Determination of amplitudes from experimental data:

- Direct Reconstruction:
 - Measurements of at least 9 observables necessary.
 - Therefore restricted to few energies and scattering angles.
- Phase Shift Analyses (PSA)
 - Amplitudes are parameterized (Legendre polynomials).
 - Only terms with small angular momenta ($J \leq 8$) are used.
 - Higher terms are approximated by virtual one-pion exchange.
 - Using the world data set simultaneously.

World Data Base



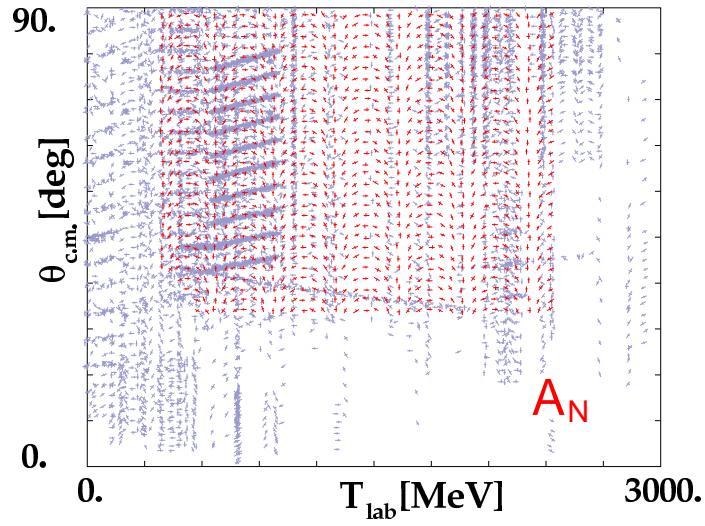
Improvement of Phase Shift Analyses:

Measurement of many different observables over a large angular and momentum range with high relative accuracy.

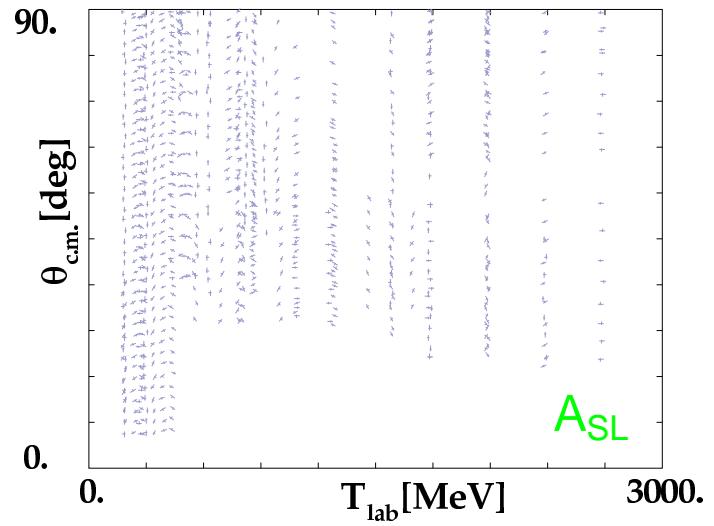
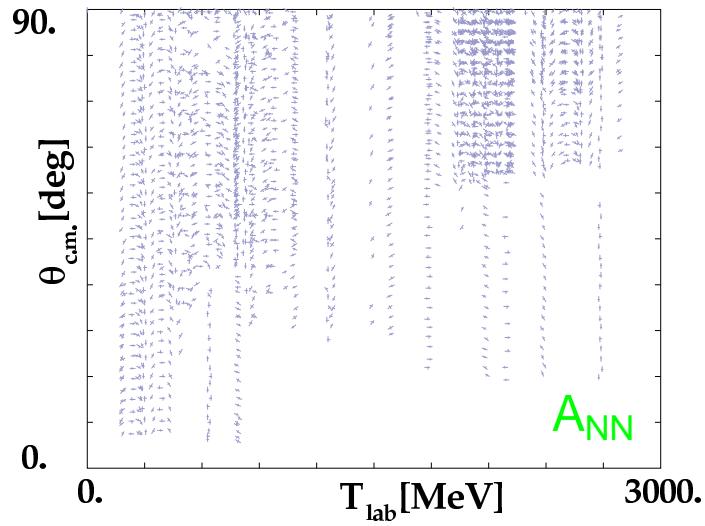
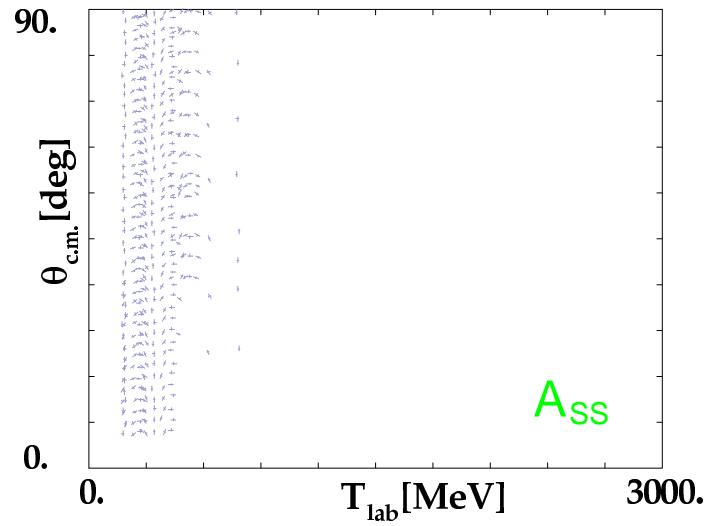
EDDA :

$$\frac{d\sigma}{d\Omega} \quad A_N$$

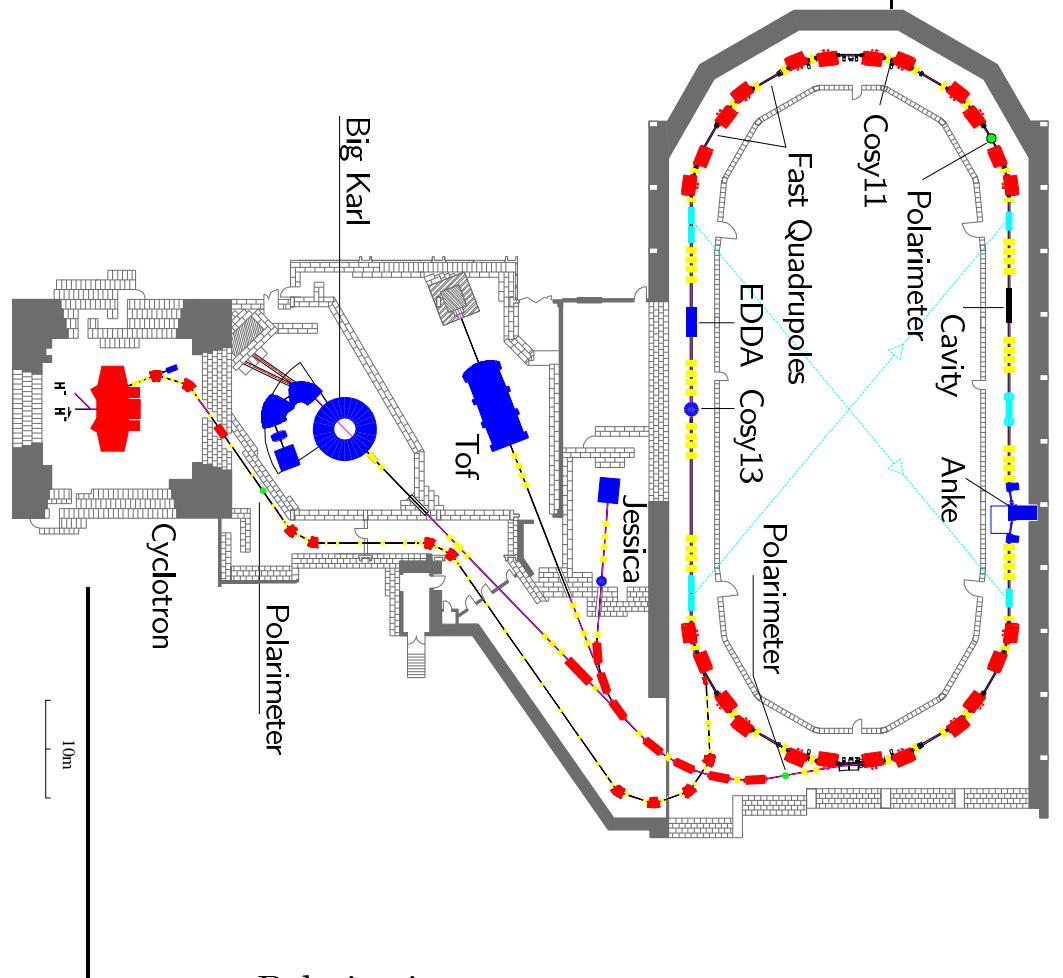
A_{SS} A_{NN} A_{SL}



Phys. Rev. Lett. 85(2000) 1819



The Cooler Synchrotron COSY

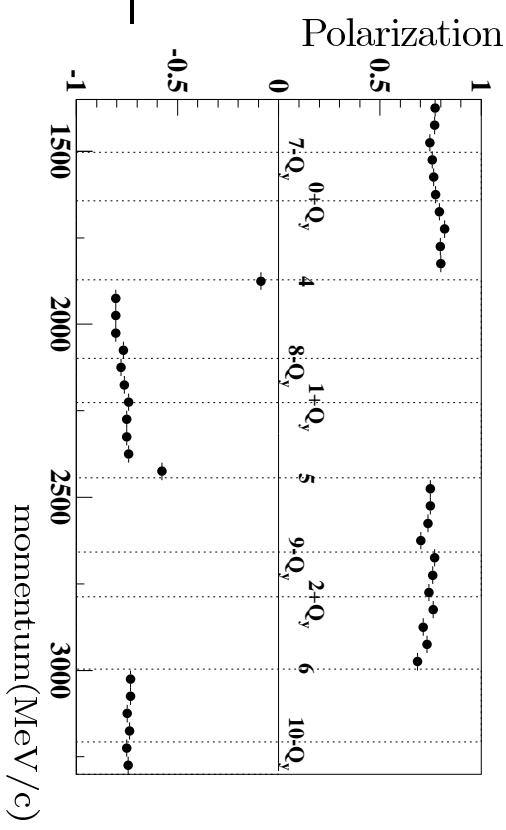


COSY

- Circumference: 184 m
- $40 \text{ MeV} \leq T_p \leq 2500 \text{ MeV}$

The polarized beam

- Polarized Source (CBS-Type)
- Polarization at the highest energies $\approx 65\%$
- Number of protons $\leq 4 \cdot 10^9$

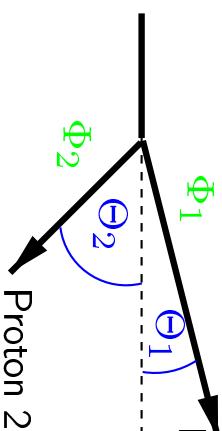


The EDDA detector

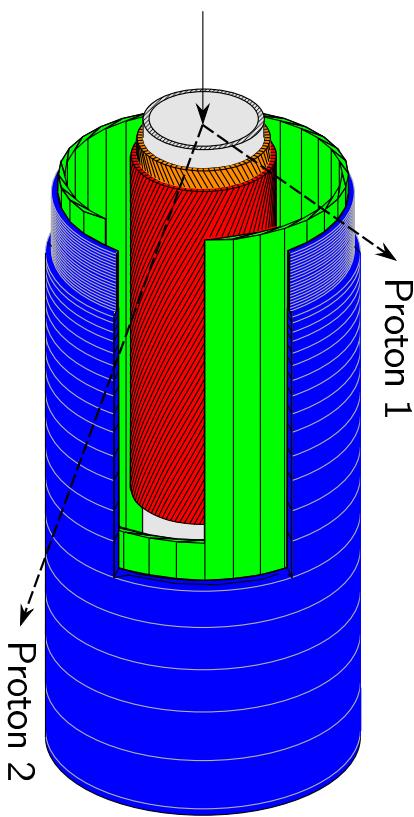


Signature of the elastic pp scattering

- Coplanarity : $\Phi_1 - \Phi_2 = \pi$
- Kinematic correlation: $\tan(\Theta_1) \cdot \tan(\Theta_2) = 1/\gamma_{cm}^2$



Detector Design



32 scintillator bars	2 x 20 semi rings	fiber double layer	640 scintillating fibers
(65x7x1000 mm)	(14...94 x 23 x 520 mm)	(2 x 2 x 520 mm)	(2.5 mm diameter)

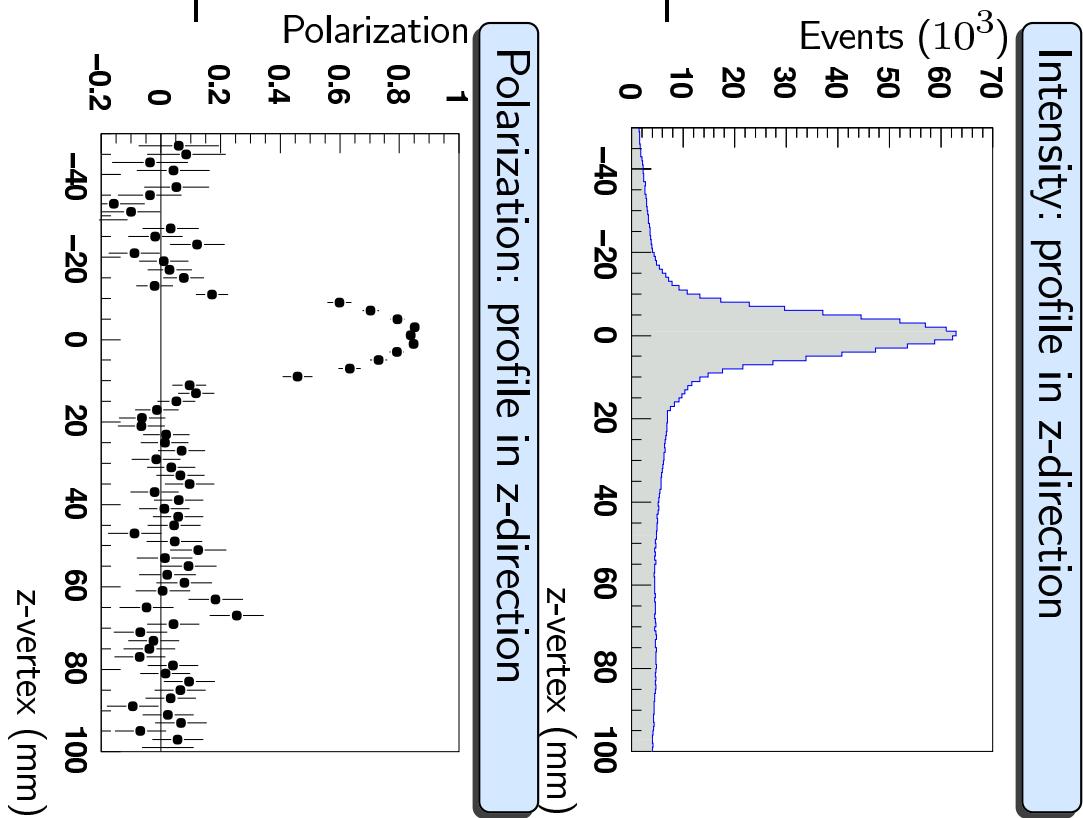
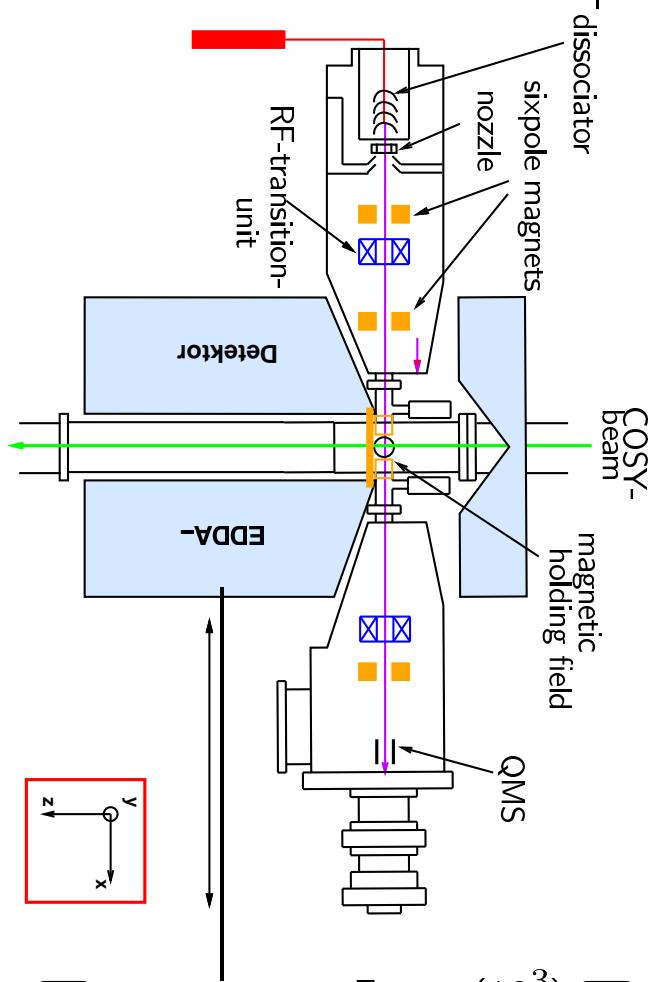
Vertex Reconstruction

Event reconstruction:

- Positions of hits in the inner and outer detector layer are determined
- Fitting of two trajectories to the observed hit pattern
- **Constraint: Signature of the elastic scattering**
- χ^2 of the kinematic fit is used to identify elastic events

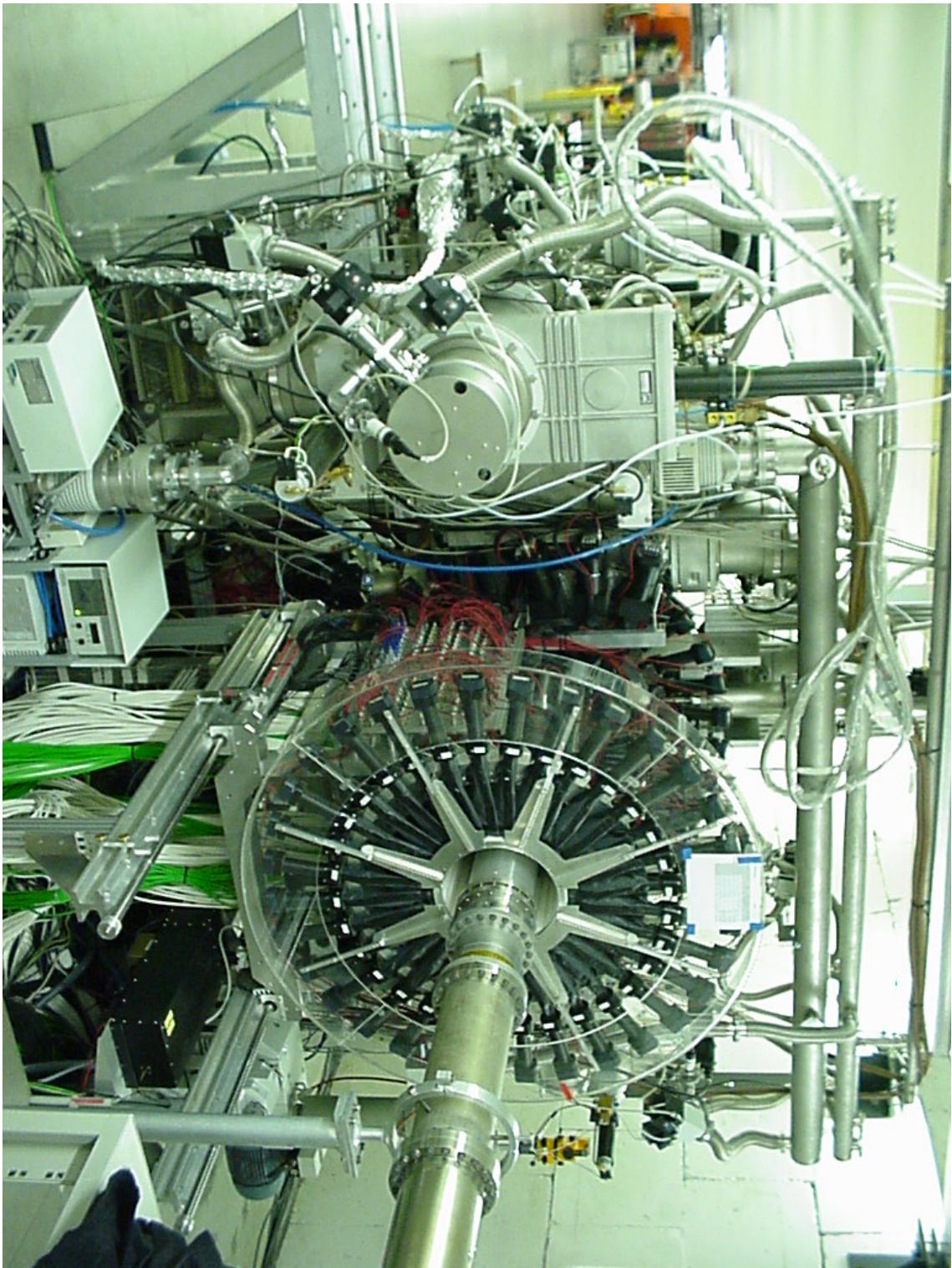
Resolution of vertex reconstruction ≤ 2 mm

Polarized Atomic Beam Target



- Target thickness: $\approx 1.8 \cdot 10^{11}$ Atoms/cm²
- Luminosity: $\approx 9.0 \cdot 10^{26}$ cm⁻²s⁻¹
- Effective polarization: 70%—75%
- Holding field: ≈ 1 mT

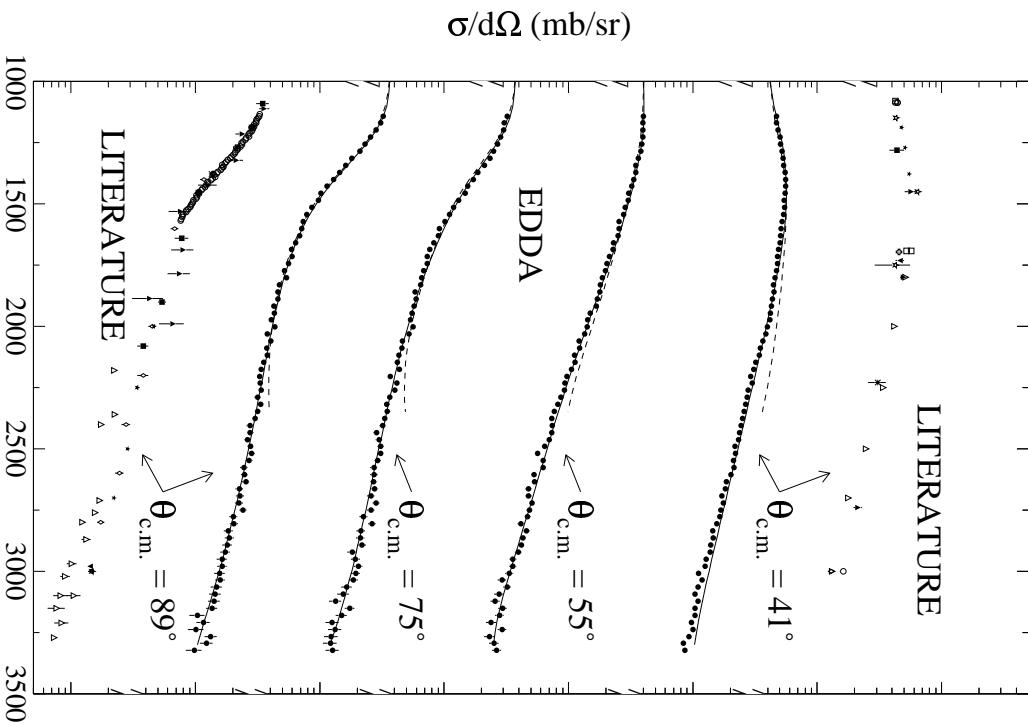
The EDDA detector



Unpolarized diff. cross section



Excitation Functions



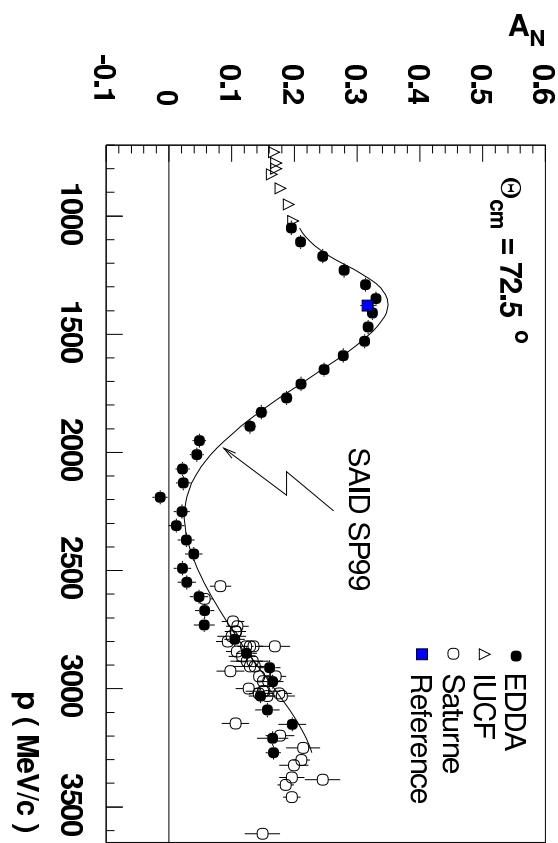
- Using $(4\mu m \times 5\mu m)$ CH₂ fiber targets and the unpolarized COSY beam.
- Two independent relative luminosity monitors
 - Measurement of the total yield of secondary electrons
 - δ -electrons from p - e scattering,
- They agree within 2.5% for all energies.
- Absolute normalization established at 1455 MeV/c.
- Improvement of PSA.
- Range of validity extended from 1.6 GeV to 2.5 GeV.
- Published in Phys. Rev. Lett. 78(1997), 1652.

Measurement of the Analyzing Power

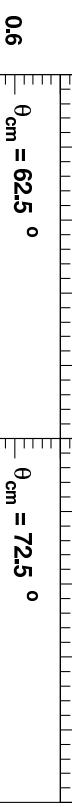
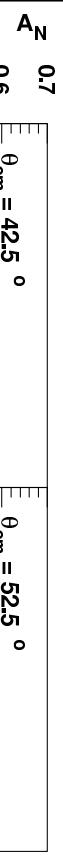


Measurement and Normalization

- Unpolarized COSY beam
- Polarized atomic beam target ($\pm Q_x, \pm Q_y$).



Results



- Measurement during acceleration and deceleration
- Target polarization was normalized at one fixed energy (730 MeV)

- Published in Phys. Rev. Lett. 85(2000), 1819.

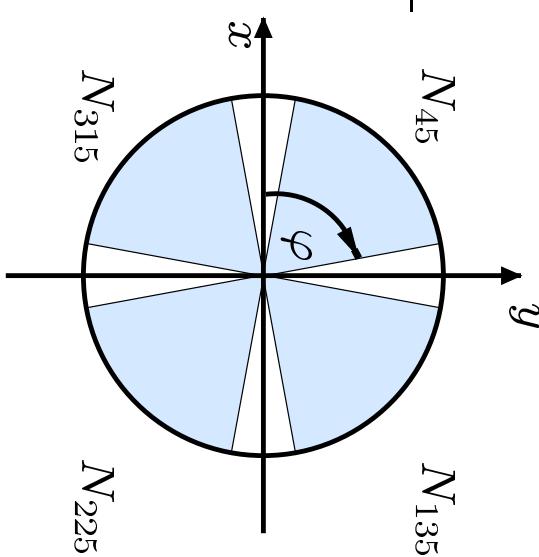
Determination of the spin correlation coefficients



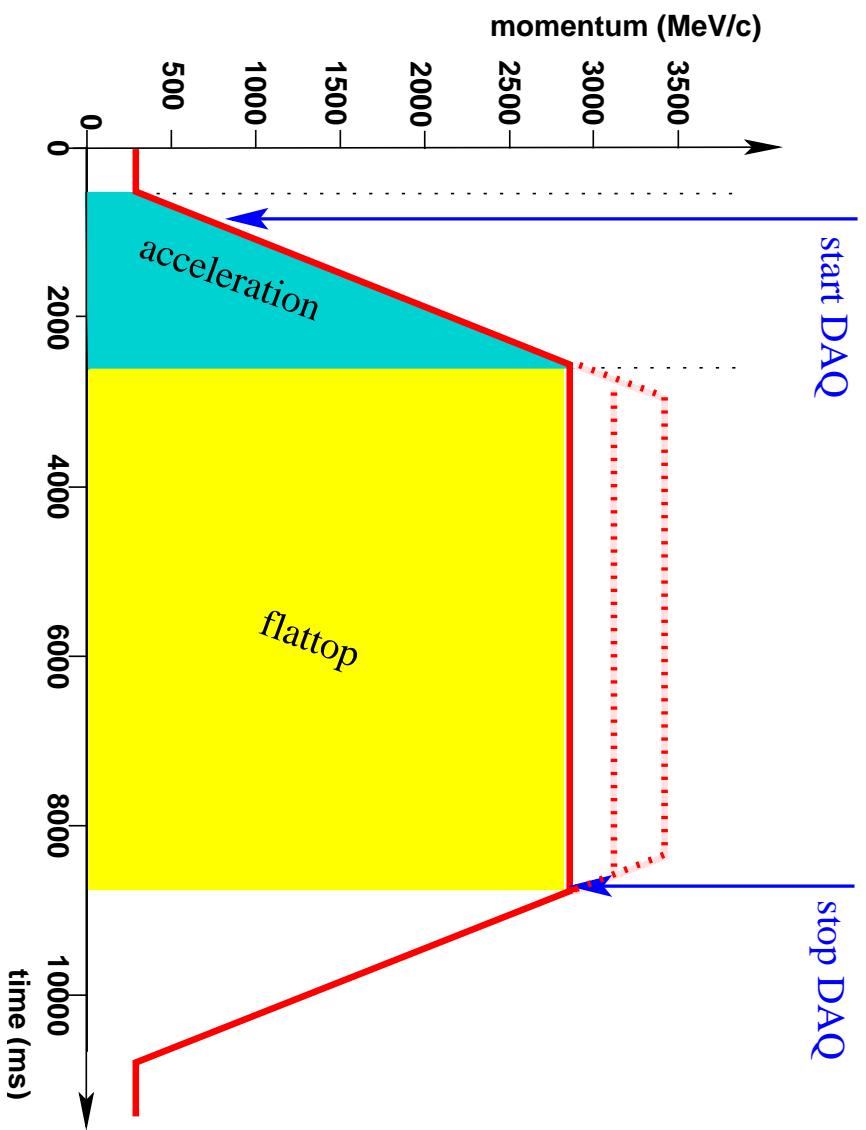
Cross section for elastic $\vec{p}\vec{p}$ -scattering:

$$\begin{aligned} \frac{d\sigma}{d\Omega}(\theta, \varphi) = & \left(\frac{d\sigma}{d\Omega} \right)_0(\theta) \cdot \left\{ 1 + \text{AN}(\theta) [(P_y + Q_y) \cos \varphi + Q_x \sin \varphi] \right. \\ & + \text{ASS}(\theta) [P_y Q_y \sin^2 \varphi + P_y Q_x \cos \varphi \sin \varphi] \\ & + \text{ANN}(\theta) [P_y Q_y \cos^2 \varphi - P_y Q_x \cos \varphi \sin \varphi] \\ & \left. + \text{ASL}(\theta) [P_y Q_z \sin \varphi] \right\} \end{aligned}$$

- Cross section shows φ -dependence
- Different count rates in four segments
- Observables can be determined by measuring count rate asymmetries.
- Independent determination: Simultaneous fit of the cross section to the observed φ -dependence.



COSY cycle

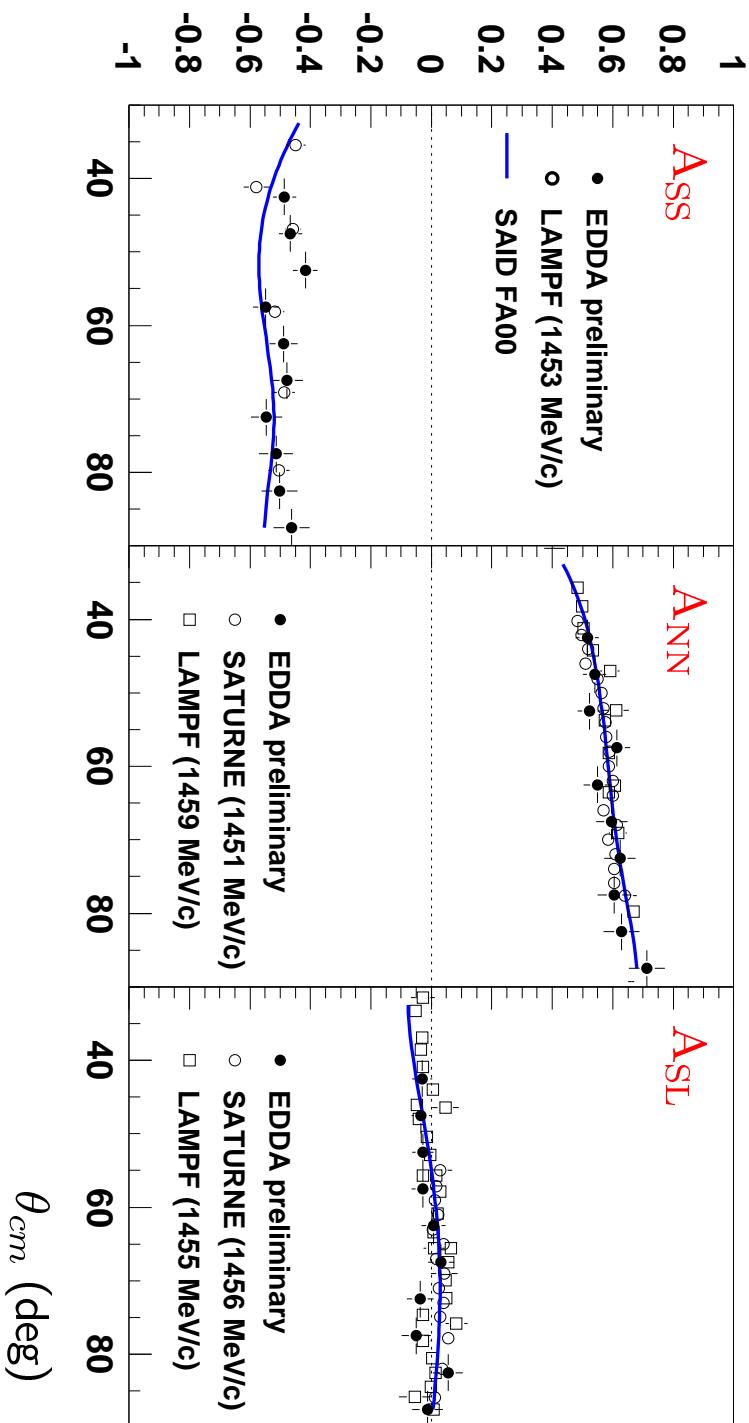


- Measurement during beam acceleration and the following flattop
- Measurements at flattop energies should cover the higher energies where the cross section is small
- Beam and target polarizations are changed with every acceleration cycle to reduce systematic errors

Results



Momentum 1430 MeV/c

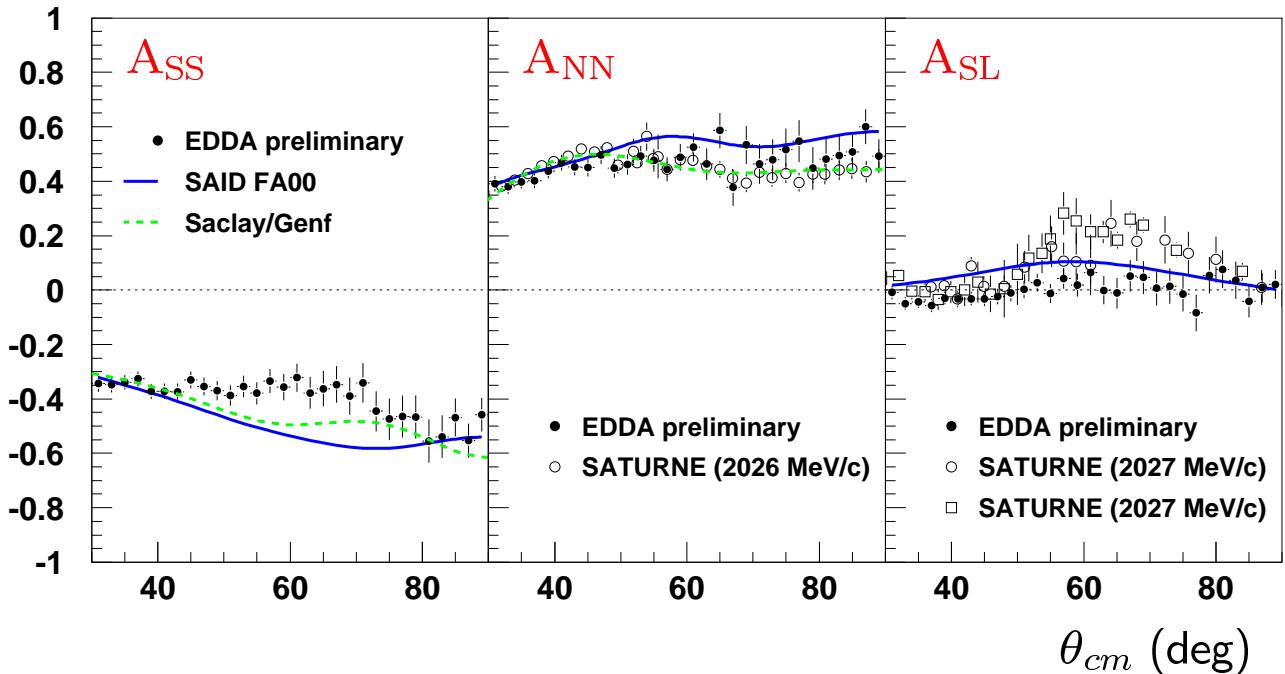


- The results of the EDDA experiment are in good agreement with other data
- Data is well described by phase shift analyses

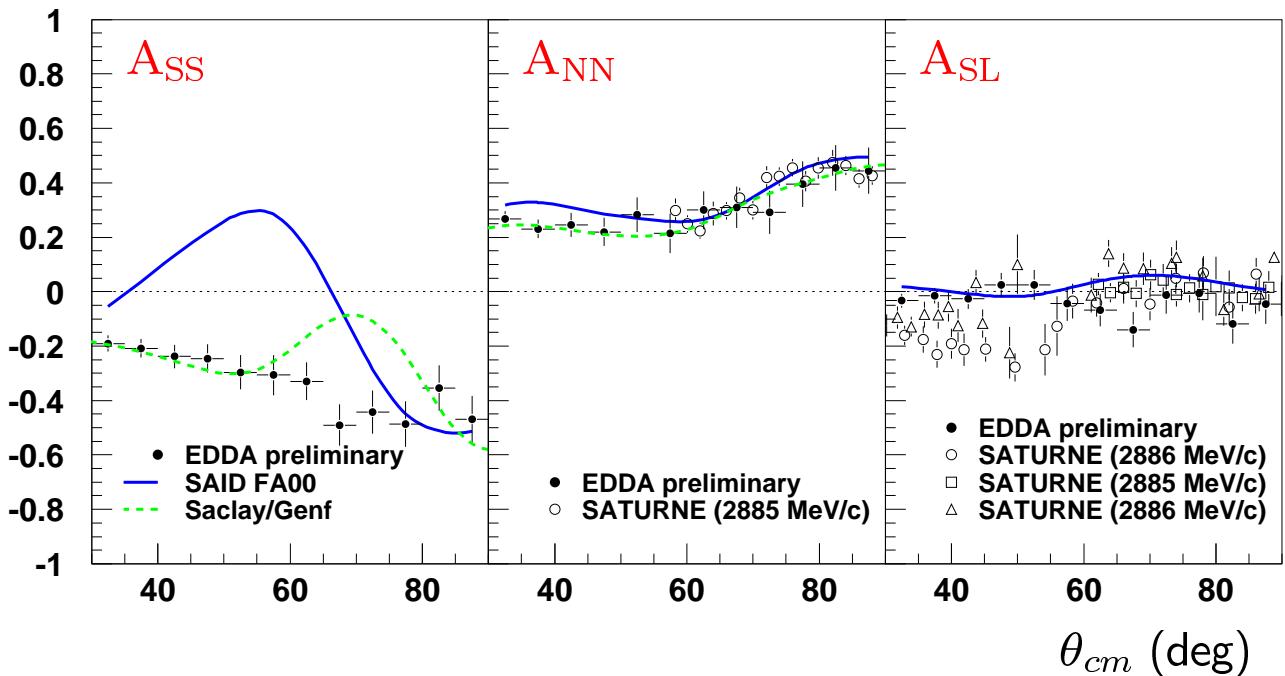
Results



Momentum 2096 MeV/c



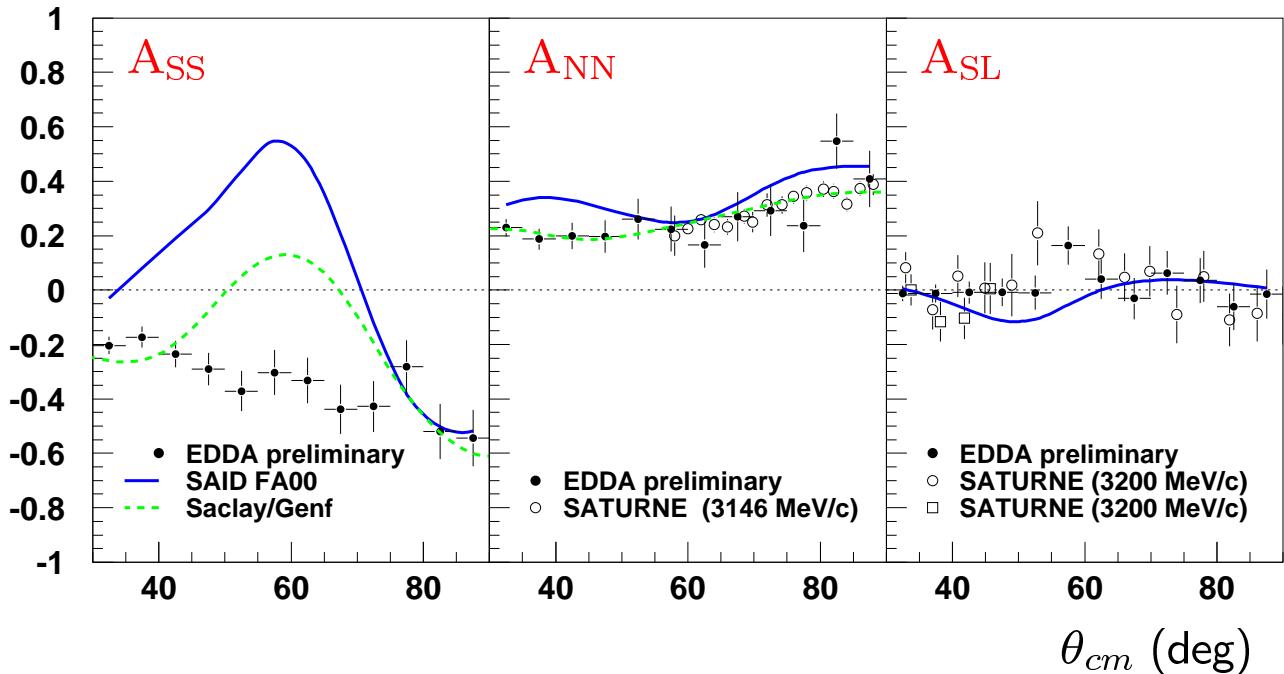
Momentum 2900 MeV/c



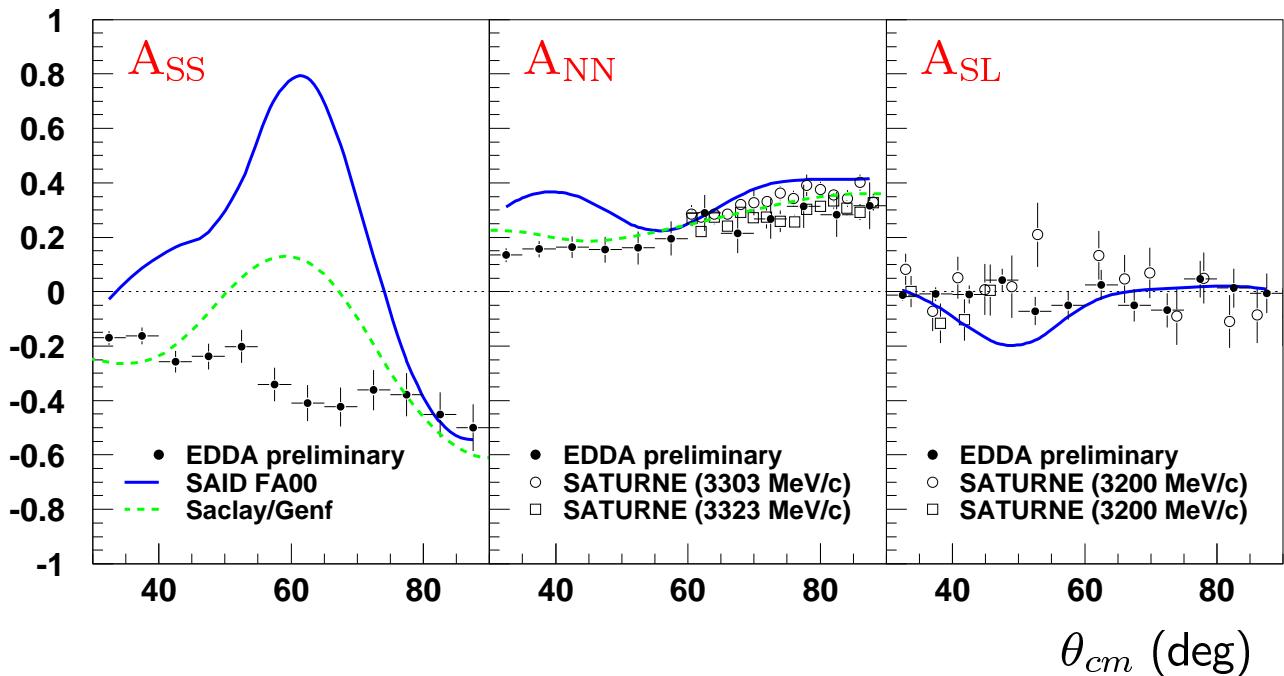
Results



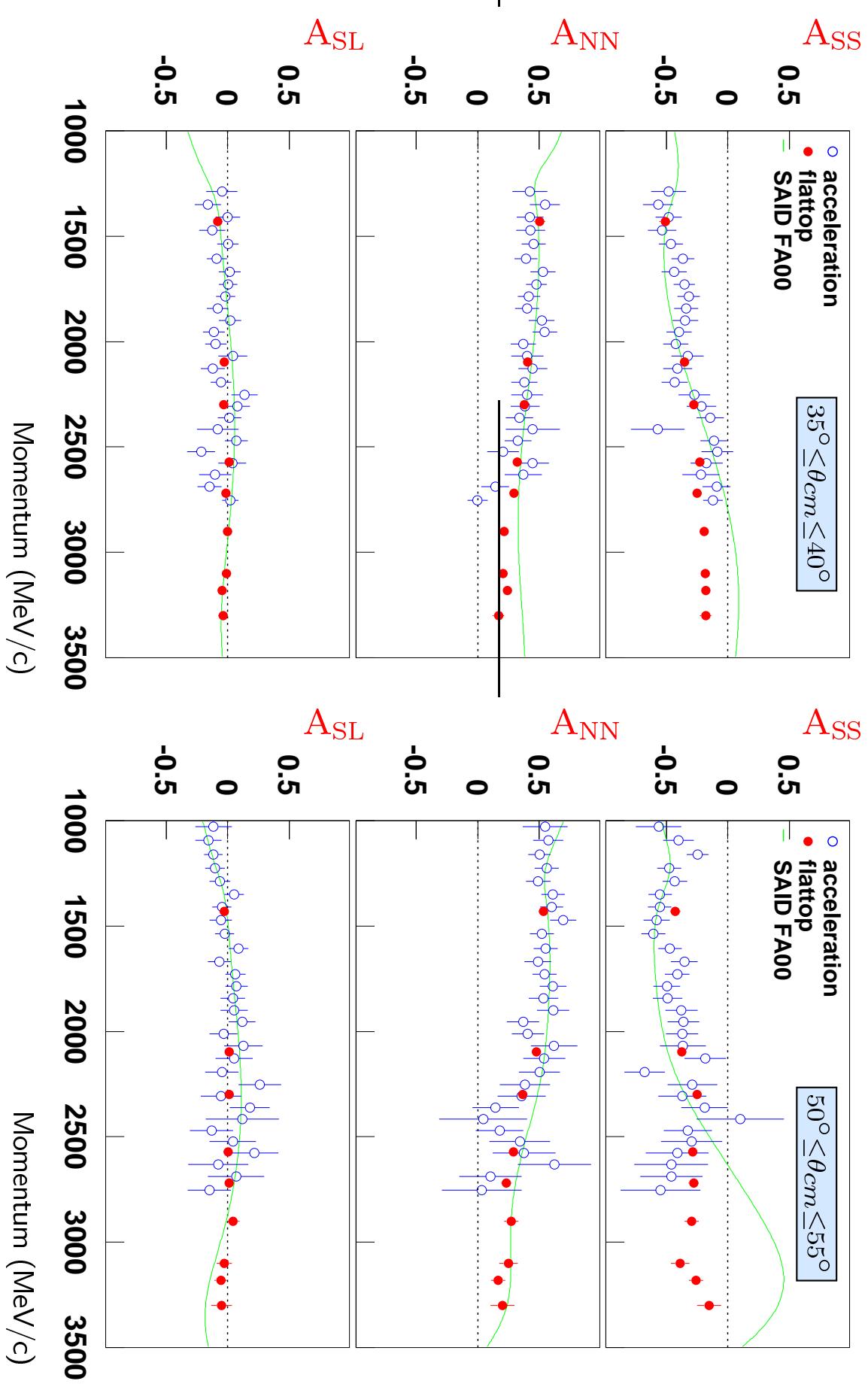
Momentum 3100 MeV/c



Momentum 3300 MeV/c



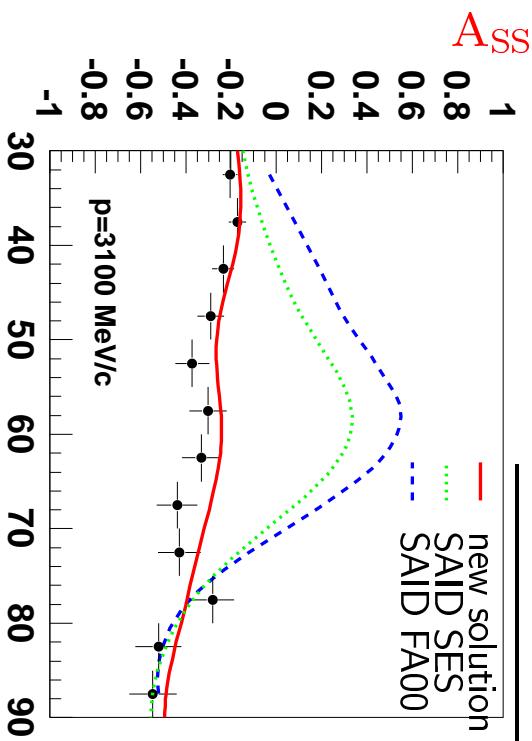
Excitation Functions



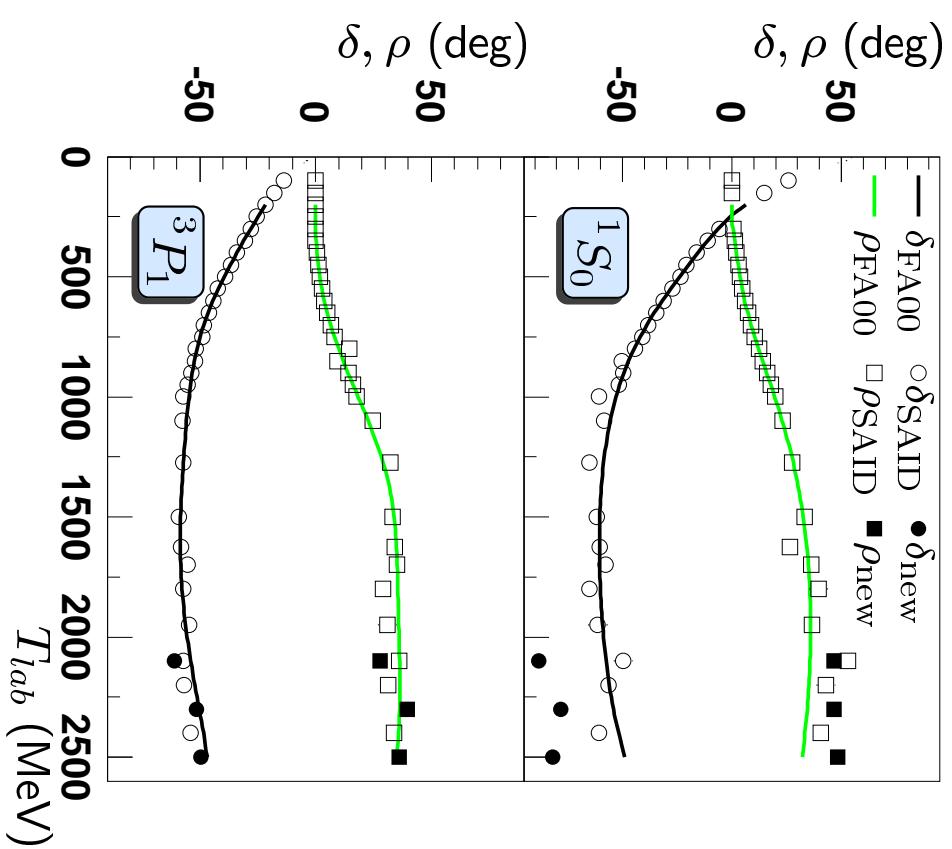
Phase Shift Analyses: Single Energy Solutions



Description of Observables



Changes of Phase Shifts

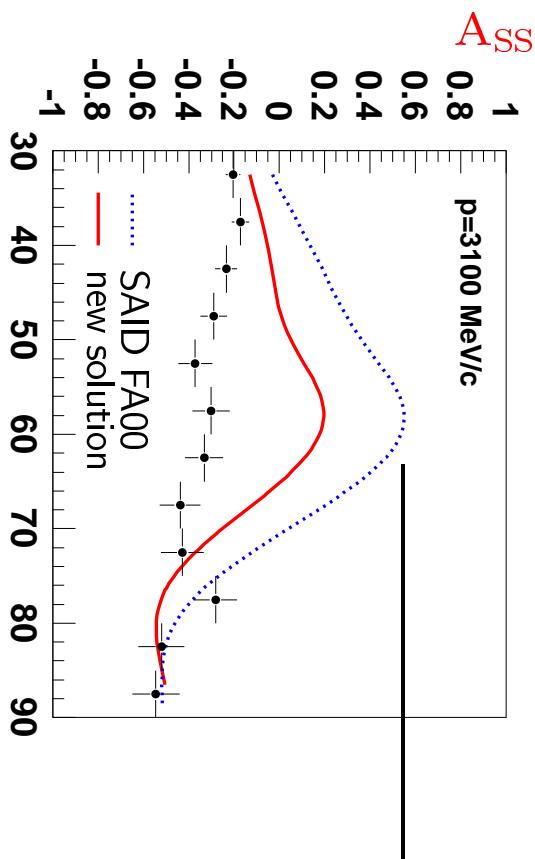


- Changes of some phase shifts at higher energies.
- Ambiguities of PSA can be resolved at some scattering angles.
- Good description of the observables.

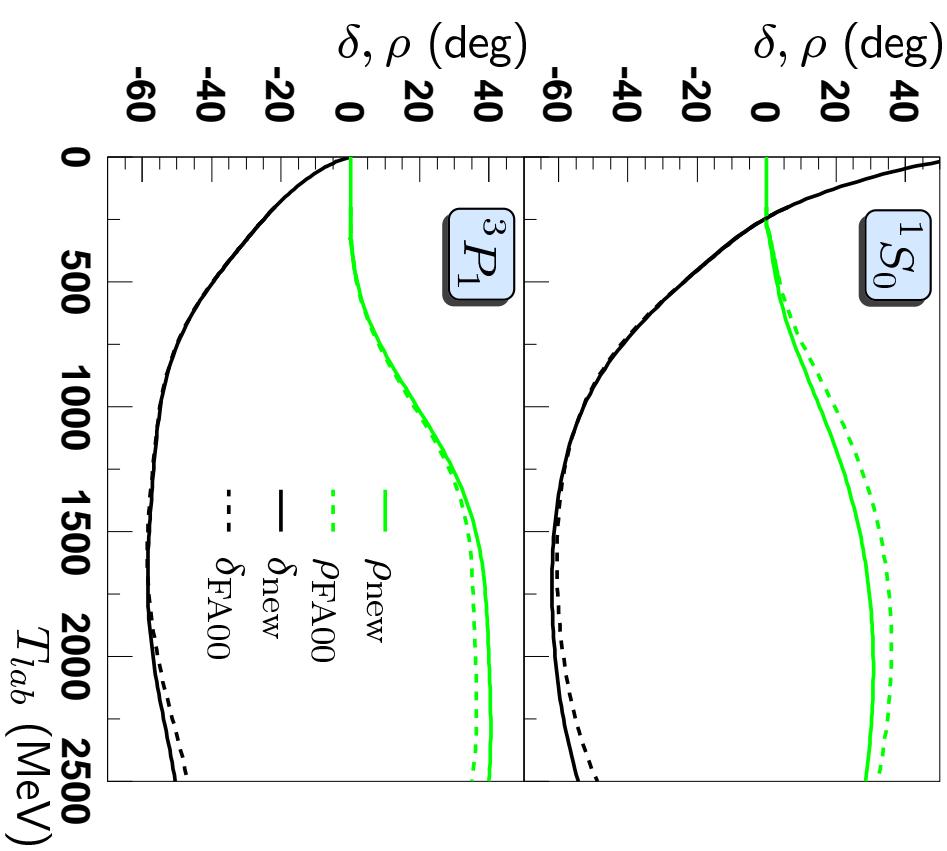
Phase Shift Analyses: Global Solutions



Description of Observables



Changes of Phase Shifts



- Adding 270 data points
- Using an old solution as a starting point
- Performing a new PSA

Outlook: Theoretical Improvements

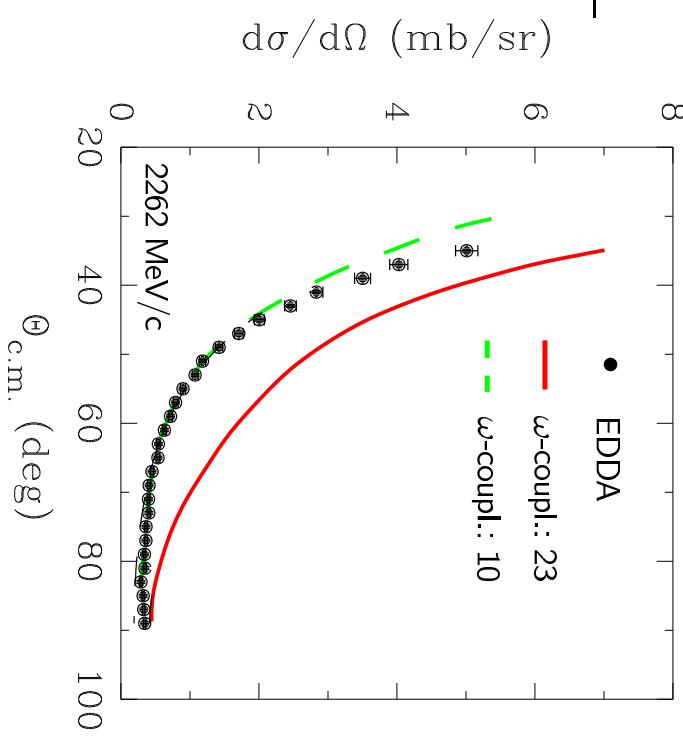


Better PSA predictions lead to a better understanding of the NN interaction at intermediate energies:

Extension of meson exchange models to higher energies by:

- **Fading in optical models**
- **Fading out meson exchange potentials**

Fading out meson exchange models is realized by reducing coupling constants of the mesons.



Summary



- **Data for the unpol. diff. cross section and the analyzing power have been published.**
 - Extension and improvement of existing phase shift solutions.
 - No evidence for dibaryonic resonances has been found.
- **Measurements of the three spin correlation coefficients A_{SS} , A_{NN} and A_{SL} have been accomplished.**
 - Systematic error smaller than 0.01
 - Overall normalization uncertainty : 4.7%
 - In general good consistency of the EDDA data with data from other experiments (SATURNE and LAMPF).
- **Comparison with existing phase shift analyses**
 - Deviations between PSA and EDDA data in kinematic regions where the data base is poor
 - First investigations show a substantial influence of the EDDA data on existing PSA
 - Some ambiguities in phase shift solutions can be resolved.